EFFECT OF MOISTURE CONTENT OF A SANDY SOIL ON ITS NITROGEN FIXING POWER

C. B. LIPMAN AND L. T. SHARP

Since attention to the well being of the beneficial soil bacteria is admittedly a vital factor in the maintenance of soil fertility, it becomes as important a question to determine the relation of a soil's moisture content to its bacterial activity as to ascertain the relation thereof to the growth of the plant itself. Relatively little work has thus far been carried out along such lines, and such data as we have bear, so far as we are aware, almost wholly on the relation of the soil's water content to ammonification, nitrification, and dentrification. Nothing but the one investigation below named, which is possessed of any cogency, has thus far come to our notice which deals with the aspects of the same question with regard to nitrogen fixation. The writers therefore present in this paper a series of interesting results bearing on the subject in question which were obtained in the course of some of their studies on the natural nitrogen fixing flora of soils.

The history of the general subject of the relation of soil moisture content to bacterial activity, as above intimated, records but few investigations. Those possessed of any cogency here are those of ENGBERDING,[1] LIPMAN and BROWN,[2] COLEMAN,[3] DEHERAIN,[4] and KRAINSKY.[5] The first named investigator found that the number of bacteria increased with the water content of the soil until the latter reached 80 per cent of saturation, and that it decreased when moisture was supplied in greater quantities. LIPMAN and BROWN found in a neglected clay loam soil that ammonification increased with the increase in water content even up to

[1] Cited from Exp. Sta. Record **21**: 1909, p. 620.

[2] N.J. Exp. Sta. Rpt. 1908, p. 105.

[3] Cent. Bakt. **20**^{2}: 1907–1908, pp. 401 and 484.

[4] Compt. Rend. **125**: 1897, p. 282.

[5] Cent. Bakt. **20**^{2}: 1907–1908, p. 732.

35 per cent of the weight of the soil. They found, however, that nitrification was most active in the same soil with a moisture content of 15 per cent, was only slightly less active with 10 per cent of moisture, and even quite appreciable with 5 per cent of moisture. COLEMAN in working with a loam soil found nitrification in it most active with a moisture content of 16 per cent, thus agreeing with the results of LIPMAN and BROWN. Contrary to the results of the latter, however, COLEMAN obtained marked reduction in nitrification when the moisture content of the soil was reduced to 10 per cent, but again obtained similar results to those of the other investigators when the moisture content of the soil was increased to 26 per cent. DEHERAIN'S findings, in work with the nitrifying flora, were in harmony with those of the foregoing investigations on nitrification. KRAINSKY in working with the nitrogen fixing flora found nitrogen fixation considerable even in soil with less than one-fourth of the optimum moisture content.

In our work on nitrogen fixation a light sandy soil from a walnut grove in Anaheim, California, was employed, and the natural nitrogen fixing flora thereof studied in its relations to moisture. The soil culture method was used in which 50 gram portions of soil were mixed in tumblers with 1 gram of mannite and water added in varying quantities as indicated in the table below. The mixture was stirred with a sterile spatula, the tumblers covered with Petri dish covers and incubated at 28°–30° C. for 21 days. Other explanatory data along with the amount of nitrogen fixed in the cultures with varying quantities of moisture are given below in table I.

It is evident from the figures in the foregoing table that nitrogen fixation in a sandy to sandy loam soil by means of its natural flora and under optimum temperature conditions takes place most actively with a water content varying from 20 to 24 per cent based on the air dry weight of soil, or 22.5 to 26.5 per cent based on the water free soil. Even with 28 per cent of moisture (air dry basis), nitrogen fixation manifests an activity but little less potent than that just mentioned. With a moisture content of 32 per cent a marked decrease in nitrogen fixing power of the soil is evident, and a still greater decrease is noted with the largest water content employed, namely 36 per cent. None the less, it should be noted

that even at the latter moisture content notable nitrogen fixation occurs in what is virtually a saturated soil.

TABLE I

INFLUENCE OF MOISTURE CONTENT ON NITROGEN FIXING POWER OF SANDY SOIL

Culture no.	Per cent moisture air dry basis (hyg. moisture 2.5 per cent)	N found mgs.	N fixed per gram of mannite mgs.	Av. N fixed per gram of mannite mgs.
1	0	31.15	0	0
2	0	31.15	0	0
3	4	31.85	.70	.88
4	4	32.20	1.05	
5	8	34.65	3.50	3.68
6	8	35.00	3.85	
7	12	37.10	5.95	5.95
8	12	37.10	5.95	
9	16	36.75	5.60	5.95
10	16	37.45	6.30	
11	20	39.20	8.05	8.05
12	20	39.20	8.05	
13	24	39.55	8.40	8.05
14	24	38.85	7.70	
15	28	38.15	7.00	7.18
16	28	38.50	7.35	
17	32	36.40	5.25	4.55
18	32	35.00	3.85	
19	36	33.95	2.80	2.98
20	36	34.30	3.15	

With small amounts of moisture in the soil some interesting results are obtained, also, as indicated in the table. Virtually no nitrogen fixation or very little takes place with a moisture content of 4 per cent (air dry basis), but a very marked increase occurs when

8 per cent is present, and amounts of moisture equivalent to 12 per cent (air dry basis) give about the same nitrogen fixation as 32 per cent moisture.

To comment on and summarize the interesting results above given we may make the following statements.

1. Nitrogen fixation by a soil's natural flora being the algebraic sum of the activities of several classes of bacteria both aerobic and anaerobic, it must follow that the greatest fixation of nitrogen will occur at a moisture content very favorable for the most active forms of nitrogen fixing bacteria, and yet not entirely unfavorable for the less potent forms, or vice versa. In the soil in question that point seems to lie between the limits of 20 per cent and 24 per cent of moisture (air dry basis). It would appear just to conclude from these data that the aerobic forms of nitrogen fixing bacteria do best with a 20 per cent moisture content (the optimum for that soil on a physical basis). At higher percentages of moisture up to 24 per cent the anaerobic forms become much more active, while the aerobic forms are depressed in their nitrogen fixing powers. This gives us two maxima of nitrogen fixation in that soil based on the moisture content or what appears from the table to be a curve which runs along at the same plane between rather wide limits.

2. The case of nitrogen fixation with respect to soil moisture content, therefore, would seem to be analogous to that of ammonification as studied by LIPMAN and BROWN as referred to above. In both cases the end products which are measured represent the algebraic sum of the activities of both aerobic and anaerobic organisms.

3. We find in confirmation of the findings of KRAINSKY, above mentioned, that nitrogen fixation is very active even with low moisture content of the soil. Thus, with a moisture content of only 8 per cent very considerable quantities of nitrogen are fixed, and, to judge from the excellent agreement between duplicate nitrogen determinations in our work, appreciable quantities of nitrogen are fixed with a moisture content of only 4 per cent.

4. Taken as a whole, the nitrogen fixing flora of the soil with which we worked, and which may be taken as a criterion for a large variety of sands and sandy loams, behave much more like the

ammonifying flora than like the nitrifying flora with respect to moisture. This is also in harmony with other results from the point of view of factors other than the soil moisture content, which one of us has obtained with respect to the behavior of these three groups of organisms.

5. We feel, as did DEHERAIN in his work cited above, that changes in the physical constitution of a soil will seriously modify the points of maximum and minimum bacterial activity with a given moisture content. But the more exact determinations of available moisture in all soils as advocated by BRIGGS will probably indicate but slight variations from the optimum and minimum moisture contents necessary for the activity of soil organisms as determined for the ammonifying and nitrifying flora by the investigators above named and for the nitrogen fixing flora by us.

LABORATORY OF SOIL CHEMISTRY AND BACTERIOLOGY
UNIVERSITY OF CALIFORNIA